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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2015/2016

ETN4086 – MOBILE AND SATELLITE COMMUNICATIONS (TE, MCE)

15 OCTOBER 2015
2.30 p.m. – 4.30 p.m.
(2 Hours)

INSTRUCTION TO STUDENT

1. This examination paper consists of **9 pages** (including the cover page) with **4 questions only**.
 2. Each question is worth **25 marks**. **Attempt ALL questions**.
 3. Please write all your answers in the Answer Booklet provided. **Show all relevant steps** to obtain maximum marks.
 4. There is an **appendix** of useful charts, constants and formulae at the end of this question paper.
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Question 1 (25 marks)

- (a) Why does cellular network use frequency re-use? How is the real-world cell design rolled out? [6 marks]
- (b) Define roaming. Hence, list all the steps involved in Global System for Mobile Communications (GSM) roaming. [8 marks]
- (c) In the Advanced Mobile Phone System (AMPS), the two-way bandwidth available to a single operator is 25 MHz with a channel bandwidth of 30 kHz and 21 control channels. Given the system parameters as cell area = 8 km²; total coverage area = 4000 km²; frequency reuse factor, $K = 7$; average number of calls per user during the busy hour, $\lambda = 1.2$; average call holding time, $H = 100$ s; call-blocking probability = 2%. Answer the following questions:
- (i) Calculate the number of cell in the service area. [1 mark]
- (ii) How many voice channels are there per cell? [4 marks]
- (iii) Determine the total traffic carried per cell, in Erlangs/cell and Erlangs/km² using Erlang B Table and a simple straight-line interpolation if needed. [4 marks]
- (iv) Calculate the number of calls/hour/cell. [1 mark]
- (v) Calculate the number of calls/hour/km². [1 mark]

Question 2 (25 marks)

- (a) The transmission power of a cellular communication system operating at 900 MHz is 40 W. Assume free-space propagation conditions and 0 dB omnidirectional antennas at both cell-site transmitter and mobile receiver. Answer the following questions:
- (i) Express the transmitter power in units of dBm. [1 mark]
- (ii) Compute the free-space propagation path loss in dB at a distance of 100 m. [3 marks]
- (iii) How much power is received by a mobile unit at a distance of 6 km? [2 marks]

Continued...

- (b) Name and briefly describe the three (3) basic propagation mechanisms. [6 marks]
- (c) Discuss the problem of multipath propagation. How does multiple input multiple output (MIMO) antenna take advantage of multipath. [6 marks]
- (d) If a mobile received power at a reference distance $r_o = 1$ km is equal to -30 dBm, find the received powers at distances of 2 km and 20 km from the same base-station transmitter for the following path-loss models:
- (i) Free space model. [2 marks]
 - (ii) Log-distance path loss model with path-loss exponent is 3. [2 marks]
 - (iii) Discuss the results that you get in (i) and (ii). Hence, why is Okumura-Hatta model being widely used for signal prediction? [3 marks]

Question 3 (25 marks)

- (a) With the aid of a diagram, briefly describe the Second Kepler's law of planetary motion. [5 marks]
- (b) A Molnya orbit is a highly elliptical orbit with an inclination of 63.45° . The orbital parameters for a Molnya orbit are listed in Table Q3 below.

Table Q3

Period	11h 58m 2s
Inclination	63.45°
Eccentricity	e
Apogee altitude	39105 km
Perigee altitude	A_p
Visibility duration	> 8 h

- (i) Calculate the length of semi major axis of the orbit. [3 marks]
- (ii) Determine the eccentricity e and perigee altitude A_p . [3 + 3 marks]
- (iii) Determine the mean anomaly of a satellite on the Molnya orbit after 5 minutes the passage of perigee. [3 marks]
- (iv) List two (2) disadvantages of this orbit. [4 marks]

Continued...

- (c) State two (2) advantages of a Very Small Aperture Terminal System (VSAT) network as compared to a terrestrial network.

[4 marks]

Question 4 (25 marks)

- (a) In designing a satellite network, satellite link budget analysis has the parameters as shown below. Calculate (i) to (iii) in dBHz.

Uplink	
Frequency, f_U	6 GHz
Satellite transponder	
Input back-off, IBO	-15 dB
Output back-off, OBO	-10 dB
Power flux density at saturation, ϕ_{sat}	-100 dBW/m ²
Figure of merit, $(G/T)_S$	12 dB/K
EIRP at saturation, $EIRP_{sat}$	45 dBW
Downlink	
Frequency, f_D	4 GHz
Total loss in the downlink, L_D	195 dB
Receiving earth station	
Figure of merit, $(G/T)_{ES}$	30 dB/K

[Some constant values and formulas are listed in the Appendices.]

- (i) Uplink carrier-to-noise power spectral density, $(C/N_0)_U$.
[3 marks]
- (ii) Downlink carrier-to-noise power spectral density, $(C/N_0)_D$.
[3 marks]
- (iii) Overall carrier-to-noise power spectral density, $(C/N_0)_T$.
[3 marks]
- (iv) Based on the finding, analyze the results and give your own comments.
[2 marks]
- (b) Consider a 70 channel frequency division multiplexing (FDM) system with a maximum baseband frequency of 252 kHz and a specified top channel SNR of 50 dB. Assume that FDM multichannel root mean square (rms) frequency deviation, lf_{rms} is 500 kHz and multi-channel peak factor of 3.16. Determine
- (i) the bandwidth of the FDM-FM-FDMA carrier using Carson's Rule.
[2 marks]
- (ii) the FDM multichannel loading factor of $n = 70$ channels.
[2 marks]

Continued...

- (iii) the 0 dBm test tone rms frequency deviation. [2 marks]
- (iv) the carrier-to-noise ratio of the FDM-FM-FDMA system in dB. Assume channel bandwidth of 3.1 kHz and psophometric weighting of 6.5 dB. [4 marks]
- (c) Suggest two (2) topologies of network configuration in very small aperture antenna (VSAT). Justify your answer. [4 marks]

Continued...

Appendix I: Constant values

Gravitation parameter, μ	=	$3.986 \times 10^{14} \text{ m}^3/\text{s}^2$
Mean Earth radius, R_E	=	6378 km
Speed of light, c	=	$3 \times 10^8 \text{ m/s}$
Sidereal day	=	23h 56m 4.09s
Boltzmann constant, k	=	$1.379 \times 10^{-23} \text{ J/K} = -228.6 \text{ dBW/Hz K}$

Appendix II: Table of Complementary Error Function

$$\operatorname{erfc}(z) = \frac{2}{\sqrt{\pi}} \int_z^{\infty} e^{-t^2} dt \text{ for } 0 \leq z \leq 3.99 \text{ in steps of } 0.01$$

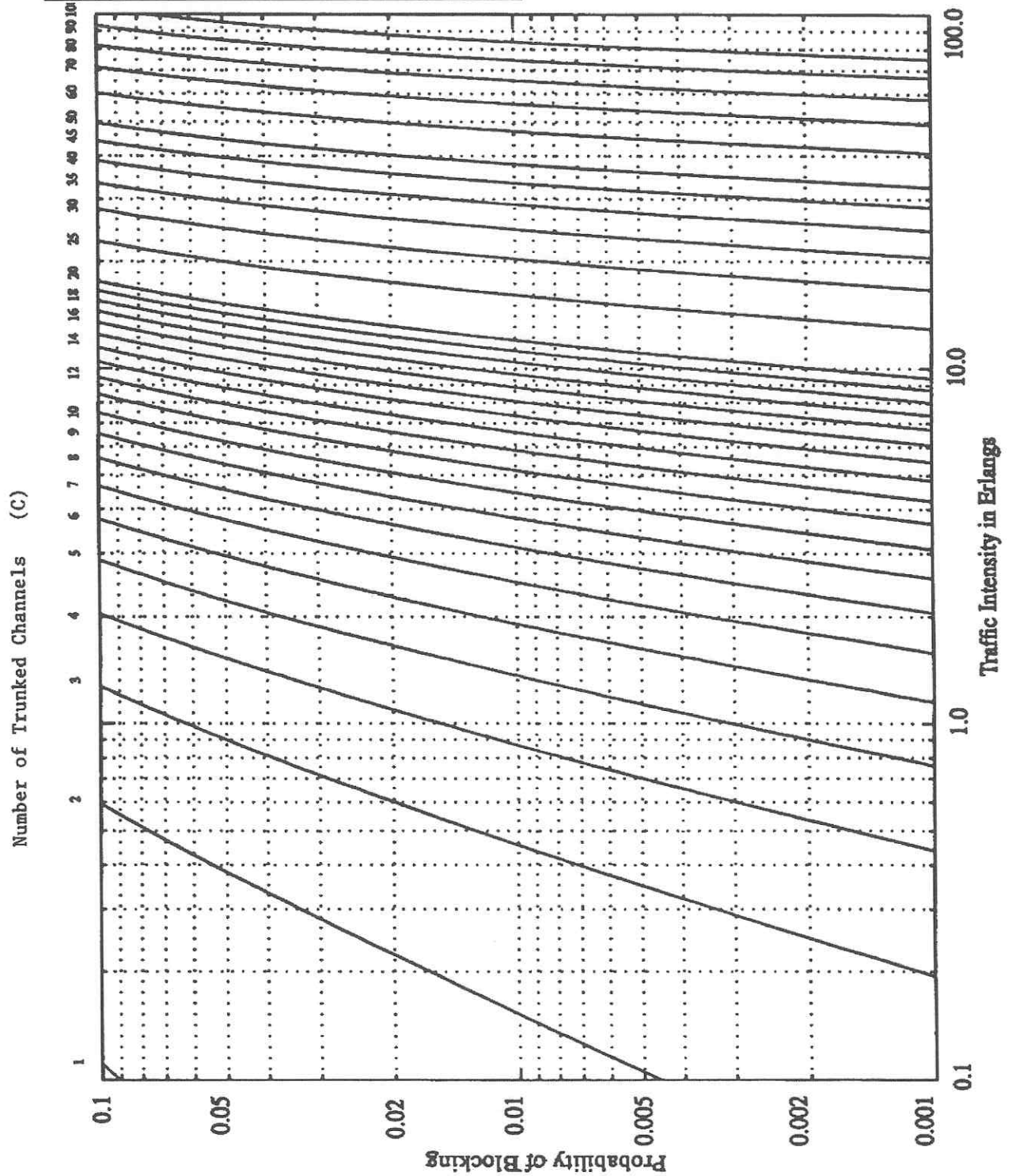
z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	1.000E+00	9.887E-01	9.774E-01	9.662E-01	9.549E-01	9.436E-01	9.324E-01	9.211E-01	9.099E-01	8.987E-01
0.1	8.875E-01	8.764E-01	8.652E-01	8.541E-01	8.431E-01	8.320E-01	8.210E-01	8.100E-01	7.991E-01	7.882E-01
0.2	7.773E-01	7.665E-01	7.557E-01	7.450E-01	7.343E-01	7.237E-01	7.131E-01	7.026E-01	6.921E-01	6.817E-01
0.3	6.714E-01	6.611E-01	6.509E-01	6.407E-01	6.306E-01	6.206E-01	6.107E-01	6.008E-01	5.910E-01	5.813E-01
0.4	5.716E-01	5.620E-01	5.525E-01	5.431E-01	5.338E-01	5.245E-01	5.153E-01	5.063E-01	4.973E-01	4.883E-01
0.5	4.795E-01	4.708E-01	4.621E-01	4.535E-01	4.451E-01	4.367E-01	4.284E-01	4.202E-01	4.121E-01	4.041E-01
0.6	3.961E-01	3.883E-01	3.806E-01	3.730E-01	3.654E-01	3.580E-01	3.506E-01	3.434E-01	3.362E-01	3.292E-01
0.7	3.222E-01	3.153E-01	3.086E-01	3.019E-01	2.953E-01	2.888E-01	2.825E-01	2.762E-01	2.700E-01	2.639E-01
0.8	2.579E-01	2.520E-01	2.462E-01	2.405E-01	2.349E-01	2.293E-01	2.239E-01	2.186E-01	2.133E-01	2.082E-01
0.9	2.031E-01	1.981E-01	1.932E-01	1.884E-01	1.837E-01	1.791E-01	1.746E-01	1.701E-01	1.658E-01	1.615E-01
1.0	1.573E-01	1.532E-01	1.492E-01	1.452E-01	1.414E-01	1.376E-01	1.339E-01	1.302E-01	1.267E-01	1.232E-01
1.1	1.198E-01	1.165E-01	1.132E-01	1.100E-01	1.069E-01	1.039E-01	1.009E-01	9.800E-02	9.516E-02	9.239E-02
1.2	8.969E-02	8.704E-02	8.447E-02	8.195E-02	7.949E-02	7.710E-02	7.476E-02	7.249E-02	7.027E-02	6.810E-02
1.3	6.599E-02	6.394E-02	6.193E-02	5.998E-02	5.809E-02	5.624E-02	5.444E-02	5.269E-02	5.098E-02	4.933E-02
1.4	4.771E-02	4.615E-02	4.462E-02	4.314E-02	4.170E-02	4.030E-02	3.895E-02	3.763E-02	3.635E-02	3.510E-02
1.5	3.389E-02	3.272E-02	3.159E-02	3.048E-02	2.941E-02	2.838E-02	2.737E-02	2.640E-02	2.545E-02	2.454E-02
1.6	2.365E-02	2.279E-02	2.196E-02	2.116E-02	2.038E-02	1.962E-02	1.890E-02	1.819E-02	1.751E-02	1.685E-02
1.7	1.621E-02	1.559E-02	1.500E-02	1.442E-02	1.387E-02	1.333E-02	1.281E-02	1.231E-02	1.183E-02	1.136E-02
1.8	1.091E-02	1.048E-02	1.006E-02	9.653E-03	9.264E-03	8.889E-03	8.528E-03	8.179E-03	7.844E-03	7.521E-03
1.9	7.210E-03	6.910E-03	6.622E-03	6.344E-03	6.077E-03	5.821E-03	5.574E-03	5.336E-03	5.108E-03	4.889E-03
2.0	4.678E-03	4.475E-03	4.281E-03	4.094E-03	3.914E-03	3.742E-03	3.577E-03	3.418E-03	3.266E-03	3.120E-03
2.1	2.979E-03	2.845E-03	2.716E-03	2.593E-03	2.475E-03	2.361E-03	2.253E-03	2.149E-03	2.049E-03	1.954E-03
2.2	1.863E-03	1.776E-03	1.692E-03	1.612E-03	1.536E-03	1.463E-03	1.393E-03	1.326E-03	1.262E-03	1.201E-03
2.3	1.143E-03	1.088E-03	1.034E-03	9.838E-04	9.354E-04	8.893E-04	8.452E-04	8.032E-04	7.631E-04	7.249E-04
2.4	6.885E-04	6.538E-04	6.207E-04	5.892E-04	5.592E-04	5.306E-04	5.034E-04	4.774E-04	4.528E-04	4.293E-04
2.5	4.070E-04	3.857E-04	3.655E-04	3.463E-04	3.280E-04	3.107E-04	2.942E-04	2.785E-04	2.636E-04	2.495E-04
2.6	2.360E-04	2.233E-04	2.112E-04	1.997E-04	1.888E-04	1.785E-04	1.687E-04	1.594E-04	1.506E-04	1.422E-04
2.7	1.343E-04	1.268E-04	1.197E-04	1.130E-04	1.066E-04	1.006E-04	9.492E-05	8.952E-05	8.441E-05	7.958E-05
2.8	7.501E-05	7.069E-05	6.661E-05	6.275E-05	5.910E-05	5.566E-05	5.240E-05	4.933E-05	4.642E-05	4.368E-05
2.9	4.110E-05	3.866E-05	3.635E-05	3.418E-05	3.213E-05	3.020E-05	2.838E-05	2.667E-05	2.505E-05	2.353E-05
3.0	2.209E-05	2.074E-05	1.947E-05	1.827E-05	1.714E-05	1.608E-05	1.508E-05	1.414E-05	1.326E-05	1.243E-05
3.1	1.165E-05	1.092E-05	1.023E-05	9.578E-06	8.970E-06	8.398E-06	7.862E-06	7.358E-06	6.885E-06	6.442E-06
3.2	6.026E-06	5.635E-06	5.269E-06	4.926E-06	4.604E-06	4.303E-06	4.020E-06	3.755E-06	3.507E-06	3.275E-06
3.3	3.058E-06	2.854E-06	2.664E-06	2.485E-06	2.319E-06	2.162E-06	2.017E-06	1.880E-06	1.753E-06	1.633E-06
3.4	1.522E-06	1.418E-06	1.321E-06	1.230E-06	1.145E-06	1.066E-06	9.922E-07	9.233E-07	8.590E-07	7.990E-07
3.5	7.431E-07	6.910E-07	6.423E-07	5.970E-07	5.548E-07	5.155E-07	4.788E-07	4.447E-07	4.130E-07	3.834E-07
3.6	3.559E-07	3.303E-07	3.064E-07	2.843E-07	2.636E-07	2.445E-07	2.267E-07	2.101E-07	1.947E-07	1.804E-07
3.7	1.672E-07	1.548E-07	1.434E-07	1.327E-07	1.229E-07	1.137E-07	1.052E-07	9.736E-08	9.005E-08	8.328E-08
3.8	7.700E-08	7.119E-08	6.579E-08	6.080E-08	5.617E-08	5.189E-08	4.792E-08	4.425E-08	4.085E-08	3.770E-08
3.9	3.479E-08	3.210E-08	2.961E-08	2.731E-08	2.518E-08	2.322E-08	2.140E-08	1.972E-08	1.817E-08	1.674E-08

Note: $1.000\text{E-}01 = 1.000 \times 10^{-1}$

$$\text{For } z > 4, \quad \operatorname{erfc}(z) \approx \frac{1}{\sqrt{\pi}} \left(\frac{e^{-z^2}}{z} \right)$$

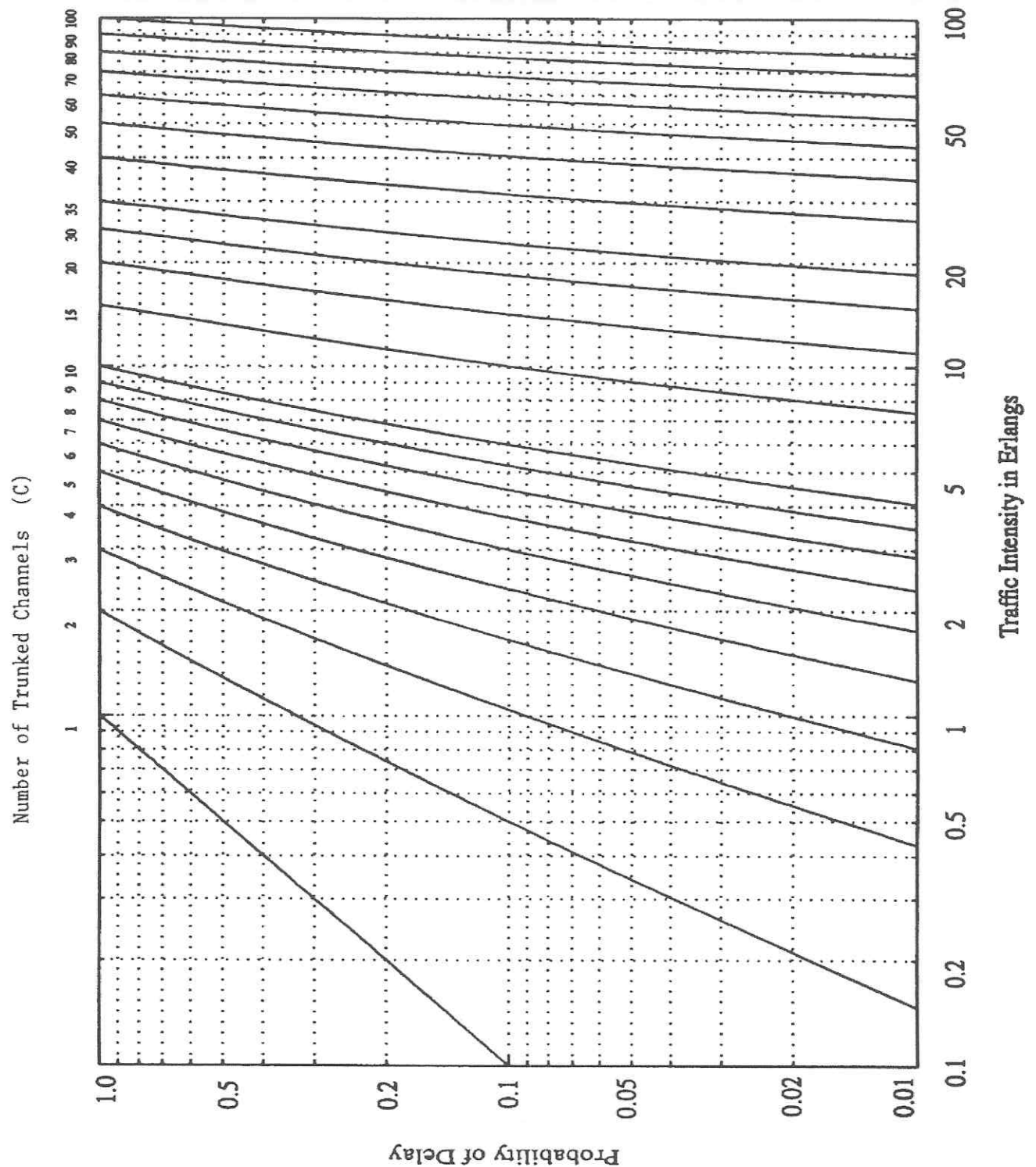
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Appendix III: Erlang B and Erlang C Chart



The Erlang B chart showing the probability of blockings as functions of the number of channels and traffic intensity in Erlangs.

Continued...



The Erlang C chart showing the probability of a call being delayed as a function of the number of channels and traffic intensity in Erlangs.

Appendix IV: Formulae

Remarks: The general formulae below may need to be modified according to the context.

Continued...

Antenna

Effective isotropic radiated power, $EIRP = P_t G_t$

Power flux density, $\phi = \frac{EIRP}{4\pi R^2}$

Received power, $P_r = \phi A_{eff}$

Antenna gain of a circular aperture or reflector of diameter D :

$$G_{max} = \left(\frac{4\pi}{\lambda^2} \right) A_{eff} = \eta \left(\frac{\pi D}{\lambda} \right)^2 = \eta \left(\frac{70\pi}{\theta_{3dB}} \right)^2, \text{ where } \theta_{3dB} = 70 \left(\frac{\lambda}{D} \right)$$

Link Analysis

Received power, $[P_r] = [EIRP] + [G_r] - [L_{total}]$

Free space loss,

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

$$PL(dB) = 10 \log \left(\frac{P_t}{P_r} \right) = -10 \log \left(\frac{\lambda^2}{(4\pi)^2 d^2} \right)$$

$$P_r(d) \text{ dBm} = 10 \log \left[\frac{P_r(d_0)}{0.001 \text{ W}} \right] + 20 \log \left(\frac{d_0}{d} \right) \quad d \geq d_0 \geq d_f$$

Log-Distance Path Loss

$$\overline{PL}(dB) = \overline{PL}(d_0) + 10 n \log \left(\frac{d}{d_0} \right)$$

Doppler shift,

$$f_d = \frac{v}{\lambda} \cos \theta$$

Noise power spectral density, $N_o = kT$

Noise factor, $F = 1 + \frac{T_e}{T_o}$

System noise temperature with reference to the antenna output,

$$T_S = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \dots + \frac{T_{en}}{G_1 G_2 \dots G_{n-1}}$$

FDM-FM-FDMA Satellite System

Signal bandwidth, $B = 2(gI\Delta f_{rms} + f_{max})$

where $\log_{10} l = \begin{cases} (-1 + 4 \log_{10} n) / 20, & n \leq 240 \\ (-15 + 10 \log_{10} n) / 20, & n > 240 \end{cases}$

Relationship between C/N and S/N is given by:

$$\frac{C}{N} = \left(\frac{S}{N} \right) \left(\frac{b}{B} \right) \left(\frac{f_{max}}{\Delta f_{rms}} \right)^2 \frac{1}{pw}$$

End of Paper